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***Research paper***

# Design and Performance Analysis of A Parabolic Dish Solar A Concentrator for A Solar Thermal Power Plant

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**Abstract**

This research emphasizes concentrating solar technology as an efficient method to meet rising energy demands and reduce dependence on fossil fuels. Concentrating solar power (CSP) systems concentrate sunlight through mirrors to produce thermal or electrical energy, rendering them ideal for medium and large-scale renewable energy generation. This study examines the design and performance of a parabolic dish solar concentrator in CSP systems, emphasizing that it produces high-pressure steam for various industrial operations as well as solar thermal power plants. Compared to other types of solar concentrators, the parabolic dish solar collector (PDSC) has a higher concentration ratio, better thermal efficiency, and is especially well-suited for decentralized energy applications. However, key design parameters such as the aperture area of the dish concentrator, rim angle, focal length of the parabolic dish concentrator, focal point diameter, concentration ratio, and thermal modelling play a crucial role in enhancing the overall performance of the PDSC. The performance of the PDSC is studied using System Advisor Model and MATLAB software, where simulations are run to assess thermal efficiency, heat transfer rates, and energy output. The results demonstrate the feasibility and performance potential of the PDSC technologies.

***Keywords***: *Concentrated Solar Power System; Parabolic Dish Solar Concentrator; Solar Thermal Technologies.*

## 1. Introduction

The transition to renewable energy is critical in meeting rising global demand and the depletion of various fossil fuels. One of the most promising renewable technologies for supplying energy needs in the future while minimizing environmental impact is CSP.

Suman et al. (2015) assess the developments in linear Fresnel solar collectors, highlighting the essential enhancements needed for increased viability of solar thermal energy. It covers different kinds of solar collectors and innovations designed to enhance efficiency for commercial feasibility [1]. Bellos et al. (2018) analyze the practical performance of integrated CSP systems. The paper investigates the performance assessment of a linear Fresnel reflector combined with a thermal storage system, utilizing both experimental and theoretical methods [2]. Further, Ghodbane et al. (2021) examine the economic and environmental benefits of linear Fresnel reflectors [3]. Finally, Aljudaya et al. (2024) showed that LFR systems, while simpler, face higher land and maintenance costs with lower efficiency. In contrast, the proposed PDSC system offers better thermal performance, reduced land use, and modular scalability, making it more cost-effective for distributed solar thermal applications [4].

Parabolic trough collectors (PTCs) are a promising CSP generation technique for thermal power production from solar energy, meeting global energy needs. The works reviewed here focus on PTC design and performance analysis. Mohamed & Yahiya et al. (2016) investigate the development of PTCs for a 50 MW CSP plant, focusing on collector area calculations and performance simulations [5]. Praveen et al. (2018) emphasize the importance of thermal energy storage in increasing efficiency at a 100 MW CSP facility in Abu Dhabi [6]. Awan et al. (2020) present an overview of current advances in PTC technology, focusing on thermal and optical efficiency [7]. Yilmaz and Mwesigye (2018) discuss PTC optical and thermal optimization via modelling and simulation [8]. Guillen-Lambea and Carvalho et al. (2021) evaluate PTC greenhouse gas emissions, demonstrating their environmental sustainability [9]. Cuce et al. (2024) investigate thermoelectric generator-PTC integration for hybrid system efficiency. These studies demonstrate the technological advances and expanding relevance of PTCs in renewable energy solutions and sustainable energy [10].

As the globe shifts to renewable energy, CSP has made major strides in solar tower technology, which is becoming increasingly important. Boretti et al. (2019) analyze solar tower plant design, efficiency, and prospective improvements through thermal energy storage and combustion integration [11]. Awan et al. (2020) compare solar tower and photovoltaic systems, analyzing energy output, land utilization, and financial viability for decision-makers [12]. Merchan et al. (2022) explore the problems and prospects of heliostat design and thermal management technologies for high-temperature central tower facilities [13]. Xiao et al. (2022) suggest cost-effectively integrating parabolic trough collectors with solar towers to enhance energy generation [14]. Gentile et al. (2024) optimize external receivers

thermally and materially. These studies enhance our understanding of solar tower technology and emphasize the need for efficiency improvements and system optimization to make CSP technologies more practical [15].
Technologies utilizing solar parabolic dishes for concentrated solar power systems have emphasized enhancing performance and efficiency. Hafez et al. (2016) model Stirling engine designs to determine how materials and configurations affect performance and research global solar dish system implementation and design optimization [16]. Zayed et al. (2020) present a Multi-Objective Particle Swarm Optimization model, illustrating the impact of design parameters on efficiency and output [17].
Kumar et al. (2022) examined the effect of design parameters and nano fluids on solar collector performance [18]. They reported a 10–13% improvement in receiver thermal efficiency using nano fluids over conventional fluids. This suggests a viable approach to enhance the overall efficiency of PDSC systems, while Farhat et al. (2024) use parabolic dish concentrators with Organic Rankine Cycles to show that design optimization improves performance and advances sustainable solar energy technology [19].
Recent developments in solar parabolic dish technology provide solutions that enhance the performance and efficiency of CSP systems, which are attributed to their high solar concentration ratio and wide operating temperature range. Lovegrove et al. (2011) present a scalable design for a 500 m² paraboloidal dish [20]. While Mohamed et al. (2012) concentrate on a portable technology that efficiently elevates water temperatures [21]. Babikir et al. (2020) investigate a Dish/Stirling system designed to enhance electricity accessibility in Chad, and Eterafi et al. (2021) examine the advantages of employing ultra-white glass to enhance thermal efficiency [22] [23]. Blanco and Miller et al. (2017) reviewed CST technologies, highlighting their high-temperature potential, efficiency trade-offs, and role in sustainable energy [24].

**Table 1:** Comparative Analysis of Different CSP Technologies [25] [26]

| Feature parameters of CSP | Linear Fresnel (LR) | Parabolic Trough (PT) | Solar Tower (ST) | Solar Dish (SD) |
|---|---|---|---|---|
| Range of operating temperatures (°C) | 150–400 | 150–400 | 300–1200 | 300–1500 |
| Solar concentration ratio | 35–170 | 50–90 | 600– 1000 | 1000–3000 |
| Solar tracking system | Single Axis | Single Axis | Dual Axis | Dual Axis |
| Relative cost | 5.5–7 crore | 6–8 crore | 7–9 crore | 8–10 crore |
| Overall Efficiency | 14–18% | 15–20% | 18–25% | up to 30% |
| Power cycle | Low Steam Rankine | Low Steam Rankine | High Steam Rankine | Very high Stirling Engine, Steam Rankine |
| Capacity range(MW) | 5–250 | 10–300 | 10–200 | 0.025–1 |
| Solar to electricity efficiency (%) | 8–12 | 10–16 | 10–22 | 16–29 |
| Outlook for improvements | Significant | Limited | Very significant | Significant potential via mass production |
| Land Use (hectares/MW) | 1.5-3 hectares | 2-4 hectares | 4-8 hectares | 0.5-1 hectare |
| Advantages | The overall cost of installation remains low due to the simple structure | Low installation cost and the most widely adopted CSP technology. | Elevated operating temperature ensures high efficiency. | High operating temperature contributes to excellent efficiency, even at smaller scales |
| Limitations | Low operating temperatures result in limited thermodynamic performance. | Operating temperature limits the overall efficiency. | Expensive installation, high losses, and frequent maintenance. | Initial installation is expensive |

Table 1 explores a comparative examination of four principal CSP technologies based on performance, cost, and efficiency metrics. Among them, solar dish systems show the highest concentration ratio and solar-to-electricity efficiency. Although linear Fresnel and parabolic trough systems are easier to install and less costly, their efficiency and operating temperatures are lower.
Each of the four types of CSP plants has inherent limitations that affect their efficiency, scalability, and economic feasibility. Linear Fresnel systems, which utilize flat mirrors for solar concentration, are more cost-effective but suffer from lower optical efficiency, higher energy losses, and limited thermal storage capabilities, reducing their overall effectiveness. Parabolic trough systems are one of the most commercially deployed CSP technologies, but they require high water consumption for cooling and cleaning, making them less suitable for arid regions. They also operate at moderate temperatures, limiting their thermal efficiency compared to higher-temperature CSP alternatives, and they require large land areas for installation [27]. Solar tower systems, while offering higher operational temperatures and improved storage capabilities, face challenges due to high initial capital costs, complex maintenance requirements, and various losses. The energy losses, such as optical losses from dust, misalignment, and atmospheric scattering; radiation losses from heat dissipation; and convection losses from heat transfer to air, all of which diminish their overall efficacy. Dish-Stirling systems utilize parabolic dishes to concentrate sunlight onto a Stirling engine, making them costlier than alternative CSP technologies. Their efficiency may vary due to weather conditions and the Stirling engine's sensitivity to temperature fluctuations, with each engine producing approximately 25 kW. These limitations point out the ongoing need for technological advancements to make CSP systems more competitive and sustainable in the global renewable energy market [28].
This research paper presents the design of a PDSC for a solar thermal power plant. A PDSC-type CSP plant has the potential to overcome the limitations of existing CSP technologies. The scalability issue of dish systems can be solved by developing modular, large-diameter dishes with automated tracking, making them viable for utility-scale deployment while maintaining the high efficiency of individual units. By combining the best features of all CSP technologies —scalable deployment, thermal storage, and reduced operational complexity —a parabolic dish CSP plant can serve as a next-generation solar power solution, offering cost-effective, sustainable, and reliable energy on a global scale.

# 2. Methodology

## 2.1. Mathematical modelling of PDSC

The PDSC technology is a novel approach for generating high-pressure steam and concentrated solar power. To assess this technology, a reference CSP plant with a capacity of 1 MW has been selected. The selected plant configuration is characteristic of a standard medium-scale and small-scale concentrated solar power plant that incorporates thermal energy storage, thus making it suitable for the investigation of the performance and design of PDSC technology [29].

### 2.1.1. Concentrator and receiver system geometric modelling

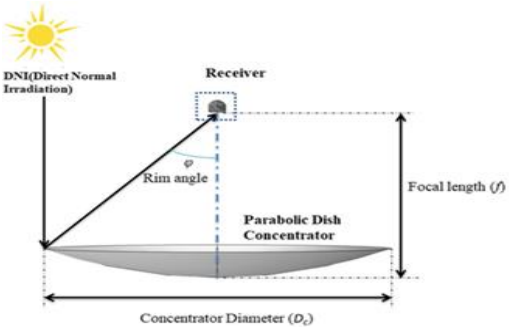


**Fig. 1:** Schematic Representation of the Parabolic Dish and Receiver.

Shape of the Collector and Receivers in PDSC:
The collector's shape is a key parameter for designing PDSC. Among various designs like flat, parabolic, and spherical mirror panels, the parabolic reflector is most effective, concentrating sunlight onto a focal point to generate high temperatures. Mirror segments direct solar rays to one point, where a receiver absorbs and transfers heat using specialized materials and fluids, boosting solar-steam and solar-to-electric conversion efficiency.
The dish concentrators' aperture area:
The aperture area ($A_{Dis}$) is the area of the solar collector that intercepts the incoming solar radiation [30]. The aperture area ($A_{Dis}$) is determined using Equation 1.

$$A_{Dis} = \frac{\pi}{4} D_{Dis}^2 \tag{1}$$

Rim angle
In a PDSC, the rim angle $\varphi_{rim}$ is the angle formed between the axis of the dish and a line drawn from the focal point to the outer edge (or rim) of the dish. This angle influences how the dish reflects and concentrates incoming solar radiation onto the focal point, directly influencing the system's efficiency and concentration ratio. Idlimam et al. [31] suggested the optimal rim angle for PDC dishes is 45 degrees.
Focal length of PDC:
The parabolic dish focuses sun irradiation into a spot where the receiver is positioned to capture that radiation. The distance between the concentrator base and the focus point is a critical component in determining the system's overall effectiveness [32]. The focal length ($F_{Dis}$) of the concentrator is determined by the aperture diameter ($D_{Dis}$) and the rim angle (φ), as expressed in Eq. 2.

$$F_{Dis} = \frac{D_{Dis}}{4\tan\left(\frac{\varphi_{rim}}{2}\right)} \tag{2}$$

Diameter of the focal point:
The focal point diameter of PDC is determined using Equation 3.

$$D_{rec} = \frac{F \times \theta}{\cos\varphi_{rim}(1+\cos\varphi_{rim})} \tag{3}$$

This diameter defines the area where concentrated solar energy is gathered, affecting both the heat absorption rate and the efficiency of solar-to-thermal energy conversion [33]. The acceptance angle (θ) refers to the angle at which solar radiation is reflected toward the focal point during brief periods of sun tracking.
Concentration Ratio
The area of the concentrator's aperture to the area of the receiver is known as the concentration ratio. This ratio is an important factor in the design of PDSC. It can be computed with Equation (4)

$$C = \frac{A_{Dis}}{A_{rec}} \tag{4}$$

**2.1.2. PDSC thermal modelling.**

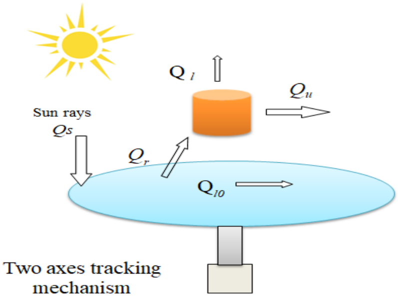


**Fig. 2:** PDSC Thermal Modelling

Thermal efficiency of a solar collector, as depicted in Figure 2, is defined as the ratio between the useful energy output and the total solar energy received at the solar concentrator's aperture. The formula in Eq. 5 is employed to determine solar thermal efficiency.

$$\eta_{th} = \frac{Q_{useful}}{Q_{solar}} \quad (5)$$

Consider the irradiation ($Q_{solar}$) received by the PDSC, with a concentrator surface area $A_{Dis}$ and direct normal irradiation Is, which can vary according to location and the orientation of the dish collector. In a steady-state system, the net solar heat transfer ($Q_{solar}$) is expressed in Equation 6.

$$Q_{solar} = I_s A_{Dis} \quad (6)$$

The amount of effective heat supplied by the collector equals the total heat gained by the heat transfer fluid inside the receiver [34]. The quantity of usable heat is determined using Equation 7.

$$Q_{useful} = Q_r - Q_l \quad (7)$$

The radiation incident on the receiver can be determined using Equation 8.

$$Q_r = I_s A_{con} \alpha_c \rho_c \tau s \quad (8)$$

The cumulative heat loss from the receiver, denoted as $Q_l$ is expressed by Equation 9.

$$Q_l = A_{rec} h_{ad} (T_{rec} - T_{amb}) \quad (9)$$

The supplied electric power by the electric generator is calculated from equation 10.

$$P_{Electric} = Q_r \cdot \eta_{turbine} \quad (10)$$

Finally, the overall system efficiency, which expresses the Total performance of the solar to electrical conversion, is given by equation 11.

$$\eta_{Over} = Q_r \cdot \eta_{receiver} \cdot \eta_{turbine} \cdot \eta_{Generator} \quad (11)$$

The efficiency can be impacted by seasonal changes in radiation offered at every region where the system is installed and commissioned.

## 3. Proposed PDSC plant technologies and plant concepts

Figure 3 illustrates the schematic representation and energy flows of a PSDC-type CSP system. In CSP systems, the three standard subsystems are the solar field (SF), thermal energy storage (TES), and power block (PB). The SF harnesses solar energy, the TES retains surplus heat, and the PB transforms heat into electricity [35]. The effective integration of these subsystems ensures reliable, continuous power generation and optimal system performance.

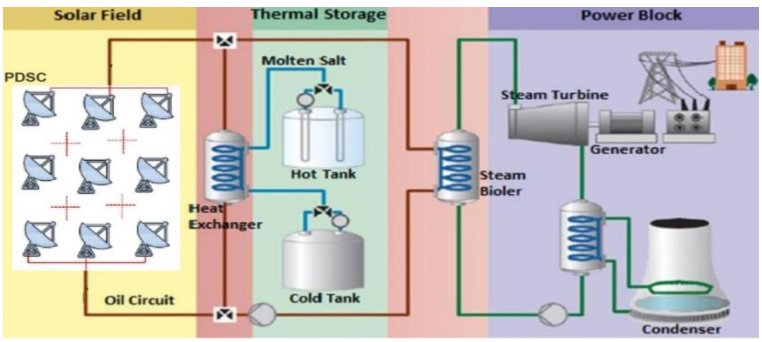


**Fig. 3:** Schematic Representation of Parabolic Dish Concentrated Solar Power Plant.

The solar field contains two primary components: a large parabolic dish collector (PDC) and a conical cavity receiver. In a CSP plant, the PDC generally consists of large mirrors installed on a tracking system that follows the sun's movement. The PDC concentrates sunlight onto conical cavity receivers positioned at its focal point. The dish tracks the sun to concentrate solar energy efficiently, while the conical cavity receiver absorbs and traps the heat for high thermal performance. This setup is known for its high temperature and efficiency, ideal for power generation in CSP systems.

A thermal energy storage system consists of two main components: a hot tank and a cold tank. This two-tank indirect storage setup, shown in Fig. 3, is employed to diminish dependence on variable weather. During periods of abundant solar energy, the surplus HTF is redirected to the TES unit. In this arrangement, molten salt (MS) is extracted from the cold tank, heated via a salt-oil heat exchanger (HX), and then delivered to the hot tank for storage. During discharge, the hot tank provides thermal energy to elevate the temperature of the cold HTF coming from the power block (PB), facilitating the generation of electrical energy.

The power generation system consists of a high-pressure turbine, a low-pressure turbine, and a condenser. Concentrated solar energy heats a transfer fluid, which then produces high-pressure steam in a heat exchanger. This steam drives the HP turbine, generating electricity, then continues to the LP turbine for further energy extraction. Afterward, the steam is condensed back into water and recirculated, maximizing efficiency.

Developing a dynamic model of PDSC for the entire system requires a few critical simplifications and assumptions, outlined below.

1) According to prime mover design, 1 MW prime movers require an operating pressure range of 38 to 42 bar steam pressure.
2) R.P.M. should be maintained at 1500 as per the standard operating condition.
3) Design criteria suggest superheated steam to be produced and delivered to prime movers, which is referred to as 40 bar and 300 degrees Celsius.
4) At 40 bar pressure, the saturation temperature is 260 degrees Celsius.

**Table 2:** The Design Specification, Physical Parameters and Performance Parameter of 1 MW Standalone PSDC System [36]

| PSDC basic specification | |
|---|---|
| Reflector shape | Parabolic dish |
| Energy conversion devices | Superheated steam |
| Construction type | Steel space frame |
| Tracking system | Dual-axis tracking |
| Design life | 30 years |
| PSDC Physical parameters | Value |
| Average reflector diameter (m) | 25 m |
| Focal length (m) | 13.4 m |
| Disc surface area (m2) | 500 m2 |
| Number of mirror panels | 380 |
| Mirror panel size (mm) | 1170 mm* 1170 mm |
| Slope error | less than 1.5 m rad |
| Typical disc spacing (center to center) (m) | 42 m |
| Average area per disc (m2) | 1764 |
| PSDC Performance parameter | Value |
| Peak reflector thermal power (kW) | 436 |
| Average concentration ratio | 2100 x for 99% capture |
| Steam temp. & pressure (bar) | 600°C / 160 |
| Receiver thermal efficiencies (%) | 97 |
| Mirror reflectivity (%) | 94.5 |
| Thermal efficiency (%) | >87 |
| Steam Output of 1 Dish (kg / Hour) | 467 |

Table 2 outlines the design specifications, physical parameters, and performance parameters of a 1 MW PSDC system. It is designed with a parabolic reflector and employs dual-axis tracking to optimize solar energy capture throughout the day. The reflector diameter of 25 meters and consists of 380 mirror panels, providing a total reflective surface area of 500 m². This solar field system generates high-temperature steam and pressure at 600°C and 160 bar, with a peak thermal output of 436 kW per disc and thermal efficiency of approximately 97%. Its design and performance characteristics make it suitable for reliable, long-term solar thermal power generation with high thermal efficiency.

**Table 3:** Technical Specifications for the Simulation of Concentrated Solar Thermal Power Plant, Vadodara, Gujarat [37] [38]

| Project | Detail |
|---|---|
| Project | Concentrated Solar Thermal Power Plant |
| Location and country | Muni seva ashram campus, Vadodara, Gujarat, India |
| Lat./Long Location | 22°20'04.0"N 73°27'53.4"E |
| Focusing | Point focus |
| Technology | Concentrated solar thermal power |
| Turbine Capacity | 1 MW |
| Steam Pressure | 38 to 42 Bar |
| Heat Transfer Fluid Type | Water |
| Cooling Method | Air |
| Solar Field obtains Temperature | 450 to 600 $^0$ C |
| Storage Type | Thermal storage |
| Static focus concentration Ratio | 2000:1 |
| Tracking | Two-axis |
| Annual solar-to-electric efficiency | 20-23 |
| Peak solar-to-electric efficiency | 25–29 |
| Power Cycle | Steam rankine |
| Solar electricity generation | 1 MW |
| Total No. of discs required for 1 MW | 10 |
| Electricity Generation Off-taker | Muni Seva Ashram trust |
| Application | Super-critical steam for power generation and different industrial heat applications |

Table 3 outlines technical specifications for the CSP plant, Vadodara, Gujarat. It uses point focus technology with two-axis tracking. It features a 1 MW steam turbine operating at a steam pressure range of 38 to 42 bar. The solar field reaches temperatures of 450 to 600°C with a concentration ratio of 2000:1, achieving an annual solar-to-electric efficiency of 20-26% and peak efficiency between 25-29%.

## 4. Results and discussion

### 4.1. Validation and simulations

The proposed Concentrated Solar Power (CSP) plant is located at Muni Seva Ashram near Goraj village in Waghodia Taluka, Vadodara, at latitude 22°20'04.0" N and longitude 73°27'53.4"E. This study focuses on the design and performance analysis of a 1 MW Parabolic Dish Solar Concentrator (PDSC) system for solar thermal power generation. To ensure accurate validation of the simulation results, benchmark data from two operational CSP plants were utilized: (1) the India One Solar Thermal Power Plant (1 MW) in Mount Abu, and (2) the Muni Seva Ashram plant. Performance metrics from these reference plants served as benchmarks and were compared with outputs obtained through MATLAB-based modelling and System Advisor Model (SAM) simulations. The thermal power output of the proposed CSP system is illustrated in Figure 4.5.

### 4.2. Dynamic system modelling using MATLAB and System Advisor Model

This study utilized MATLAB and System Advisor Model (SAM) to simulate and evaluate the performance of CSP plants. MATLAB offered flexibility for custom component modelling and supported complex simulations, making it ideal for optimizing plant performance. Meanwhile, SAM was used to model the CSP plant's performance under various operating conditions by adapting its built-in models for the solar collector and thermal storage systems to fit the PSDC system. The combination of MATLAB for detailed modelling and SAM for overall performance analysis provided a comprehensive view of the CSP plant.

Fig. 4.1 illustrates the variation in solar beam radiation (W/m²) observed on May 11, 2025. It has been noted that throughout the execution time, beam radiation increases, reaches a peak, and then begins to decrease. The peak is reached between 12:00 p.m. and 1:00 p.m., and after that, it starts to decline, though at a slower rate than it did earlier in the day.

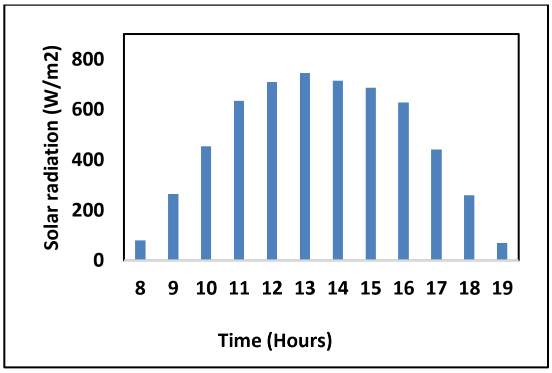


**Fig. 4.1:** Variation of Solar Beam Radiation with Time.

Fig. 4.2 illustrates how the ambient temperature changes over time. Seasonal and altitude variations both have a big impact on ambient temperature. Maximum ambient temperatures are recorded between 12:30 p.m. and 1:30 p.m. After 1:30 p.m., there is little variation until the experiments are over.

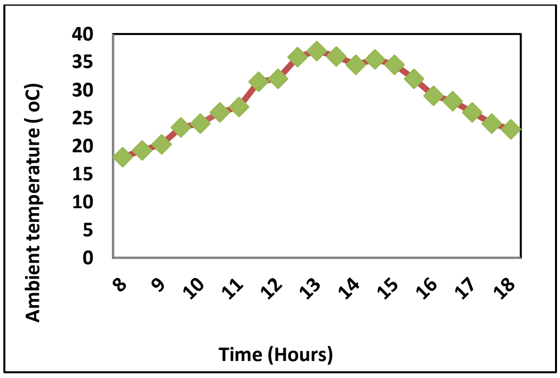


**Fig. 4.2:** Variation of Ambient Temperature with Time.

In a CSP system, temperature reaches its maximum around midday when solar radiation is at its peak, allowing the HTF to absorb and store significant energy. The maximum achievable temperature in this system is 600 $^0$C. This high-temperature phase is crucial for efficient electricity generation, as the system operates at optimal conditions. However, as the afternoon progresses and sunlight diminishes, the temperature of the HTF gradually decreases, leading to a reduction in energy production. This decline continues into the evening, where the system may rely on thermal energy storage to sustain output for a while, but ultimately, the cooling process signifies the end of effective energy generation until the next day.

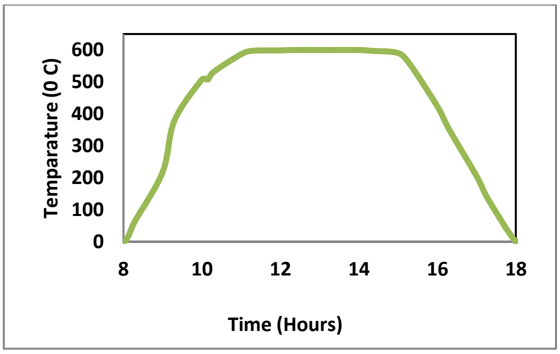


**Fig. 4.3:** Variation of Temperature with Time.

From Figure 4.4, observe that the hourly Steam Production (Kg/Hour), the average steam production of 2876 Kg. This steam can be utilized for power generation as well as high-temperature industrial applications in sectors such as the Paper, textile, food processing, chemical, and Pharmaceutical industries.

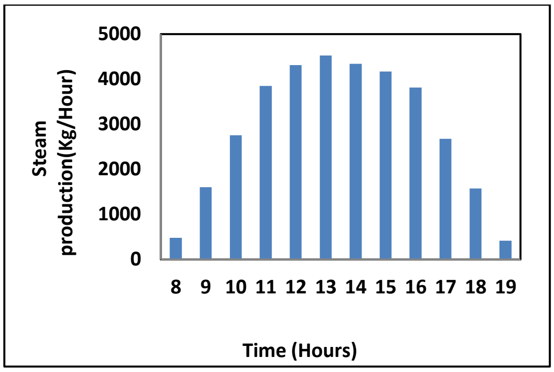


**Fig. 4.4:** Steam Production (Kg/Hour).

Fig. 4.5 shows the heat energy generation through parabolic dish solar collectors. The typical net power output profile of a CSP system with a maximum thermal power of 1 MW. The electrical output of the system is directly dependent on the intensity of solar radiation. Typically, solar irradiance increases from around 8:00 AM and reaches its peak near solar noon (around 12:00 PM to 1:00 PM), after which it begins to decline. Consequently, the net power output of the PDSC system follows a similar trend, ramping up during the morning hours, peaking around midday, and decreasing thereafter.

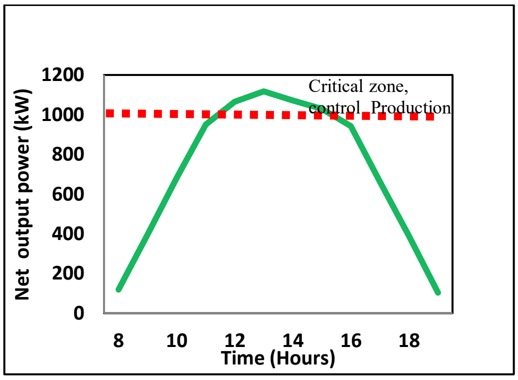


**Fig. 4.5:** Typical Net Power Output Profile of CSP.

## 5. Conclusion

This study provides a thorough design and performance assessment of a 1 MW PDSC-type CSP system for solar thermal power generation, focusing on high-temperature steam production and energy conversion efficiency. Through elaborate geometric modelling, thermal modelling, and simulations using MATLAB and the System Advisor Model, the system has been corroborated to operate efficiently under a wide range of solar and ambient conditions. With its high geometric concentration ratio and dual-axis tracking, the CSP arrangement may achieve significant thermal power generation and consistent superheated steam output that is appropriate for industrial-scale power applications. The technical viability and scalability of parabolic dish-based concentrated solar systems for decentralized, clean energy generation are confirmed by these studies.

The net power output can be maintained at about 1 MW for at least 5 hours on sunny days continuously. Net steam can be produced for more than 5 hours a day at a 4000 kg/hr rate, which can further be controlled to maintain power output through steam turbines. To further improve dispatch capability and year-round performance, future research may concentrate on incorporating cutting-edge thermal storage systems and hybridization techniques. CSP offers a sustainable substitute for traditional fossil fuels by generating electricity without burning coal or other carbon-heavy resources. CSP provides a sustainable alternative to conventional fossil fuel energy by producing electricity without the combustion of coal or other carbon-intensive sources. This substantially diminishes the total carbon footprint and facilitates the shift towards a more sustainable and eco-friendly energy generation system.

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